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(54) **Texture-hardened alpha-alumina coated tool**

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Outil revêtu d'alpha-alumine à la texture durcie

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Description**BACKGROUND OF THE INVENTION**

[0001] The present invention relates to a coated cemented carbide insert combining a substrate with a tough surface zone and a texture-hardened α - Al_2O_3 layer useful in a wide range of metal cutting operations, for example turning of steel (low alloyed steel and hardened steel) and cast irons, particularly nodular cast iron in a wide range of cutting applications where the mechanical constraints may vary significantly.

PRIOR ART

[0002] The control of the α - Al_2O_3 polymorph in industrial scale was achieved in the beginning of the 1990's with commercial products based on US patent 5,137,774. Later modifications of this patent have been used to deposit α - Al_2O_3 with preferred textures. In US 5,654,035 an alumina layer with the (1012) texture and in US 5,980,988 an alumina layer with the (112 0) texture are disclosed. In US 5,863,640 the (1012), (1014) and (112 0) textures are disclosed. US 6,333,103 describes a modified method to control the nucleation and growth of α - Al_2O_3 on the (101(10)) plane. US 6,869,668 describes a method to obtain a strong (1010) texture in α - Al_2O_3 using a texture modifying agent (ZrCl_4). The prior-art processes discussed above use all deposition temperatures of about 1000°C. US 7,094,447 describes a technique to achieve a pronounced (1012) texture. Enhanced deposition techniques to produce pronounced (1014) and (1126) textures are disclosed in US2006/0199026 and US 2006/0141271, respectively. However, the (0006) diffraction peak, which is an indication of the (0001) texture, has not been observed earlier Osada et al. studied wear mechanism of thermally transformed (001) textured Al_2O_3 layers (Journal of Refractory Metals & Hard Materials 24 (2006), 387-391). In US 2007/104945 a (0001) textured nucleated alumina layer is disclosed. The (1012), (1014) and (0001) textured alumina layers are compared and the (0001) texture is found superior to the other textures.

[0003] Methods to produce a tough binder phase enriched surface zone in the upper part of cemented carbide cutting tool inserts prior to coating are commonly referred to as gradient sintering. There are two types of processes used to produce the binder phase enriched surface zone:

- (i) By dissolution of cubic carbide phase near the surface (N-gradient) e.g. US 4,277,283, 4,610,931, 4,830,930 and 5,106,674.
- (ii) By controlled cooling or decarburisation (C-gradient) e.g. US 5,106,674 and US 4,830,930

OBJECTS OF THE INVENTION

[0004] New laws/regulations will increase the cost of the use of cooling lubricants in metals machining. This promotes dry machining. In turn, this will increase the demand for more temperature-resistant coated cemented carbides and generally forces the metal cutting industry to consider new alternative methods. The following are the most important trends in the market place:

- Higher cutting speeds, for increased productivity.
- Dry machining and/or Minimal Quantity of Lubrication (MQL), for reduced costs and environmental aspects.
- Difficult-to-machine materials i.e. high strength materials, for lighter components and constructions.

[0005] All these trends put more demands on wear resistance, together with deformation resistance and toughness. Due to its high chemical stability and favourable thermal properties Al_2O_3 is the ideal coating material for high-speed metal cutting. Due to the trends in the market place discussed above the need for enhanced wear resistance together with enhanced toughness is highlighted.

[0006] It is an object of the present invention to provide an improved alumina coated cemented carbide tool with improved on wear resistance, together with deformation resistance and toughness.

BRIEF DESCRIPTION OF THE DRAWINGS**[0007]**

Fig. 1 shows the (0006) diffraction peak at 2θ of 41.675° obtained by using $\text{Cu K}\alpha$ radiation from an α - Al_2O_3 layer according to the present invention.

Fig. 2a is a light optical micrograph in 1200X magnification of an uncoated polished cross section of the surface zone of a cemented carbide with an N-gradient. The white phase is binder phase, the light grey is WC and the dark

grey is cubic phase.

Fig. 2b is an SEM micrograph in 10000X magnification obtained using back-scattered electrons of a polished cross-section of an as deposited α -Al₂O₃ layer according to the invention deposited onto a Ti(C,N)-layer deposited on the substrate from Fig. 2a.

Fig. 3 shows a cross-section SEM micrograph of the texture-hardened α -Al₂O₃ layer according to the present invention, coating c from Example 3. The (0001) planes, which are nearly parallel to the coating surface, are arrowed.

Fig. 4 shows SEM surface images of (0001) textured α -Al₂O₃ layers c and d from Example 3, respectively. The layer according to the invention, layer c, Fig 4a is not terminated by (0001) planes, as is the layer according to the prior art, layer d, Fig 4b.

Fig. 5 shows X-ray Diffraction (XRD) patterns of the α -Al₂O₃ layers a, b and c from Example 4 ($2\theta=25-45^\circ$).

Fig. 6 shows the number of undamaged cutting edges vs. feed in mm/rev in the cutting test in Example 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0008] It has now surprisingly been found that the full advantage of the texture-hardening effect can be achieved in combination with a binder phase enriched substrate. When applied on such a cemented carbide the (0001) texture-hardened α -Al₂O₃ clearly outperforms the prior art. The effect of the cobalt enrichment is strengthened by the presence of the (0001) texture. Another surprising effect is that the (0001) texture clearly reduces the tendency for plastic deformation of the cutting edge.

[0009] Thus, the present invention combines a cemented carbide with binder phase enriched surface zone with a texture-hardened α -Al₂O₃ layer. A cutting tool insert is provided as indicated in claim 1, comprising:

a) Bulk substrate

[0010] According to the present invention a coated cutting tool insert is provided consisting of a cemented carbide body with a composition of 4-12, preferably 5-9, most preferably 6-7, wt-% Co and 5-10, preferably 7.5-9.5 wt-% cubic carbides of the metals from groups IVb, Vb and VIb of the periodic table, preferably Ti, Nb and Ta, and balance WC, preferably 83-87 wt-% WC. The ratio between the weight concentrations of Ta and Nb is between 1.0 and 3.0, preferably 1.5 and 2 and of Ti and Nb 0.5-2.0, preferably 0.8-1.2.

[0011] The cobalt binder phase is preferably highly alloyed with tungsten. The concentration of W in the binder phase may be expressed as the S-value = $\sigma / 16.1$, where σ is the magnetic moment of the binder phase in $\mu\text{Tm}^3\text{kg}^{-1}$. The S-value depends on the content of tungsten in the binder phase and increases with decreasing tungsten content. Thus S=1 for pure cobalt, or for a binder saturated with carbon. Further, it is noted that S=0.78 for a binder phase that contains W in an amount corresponding to the borderline to formation of η -phase. S should be slightly above the borderline value of 0.78, preferably within the range 0.79-0.90, most preferably 0.80-0.85.

[0012] The mean WC grain size expressed as coercivity is 9-18, preferably 10-15, most preferably 11-13 kA/m.

b) Cobalt enrichment

[0013] The thickness of the binder phase enriched layer in the surface region of the cemented carbide bulk is 5-50, preferably 10-30, most preferably 15-25 μm . It has an average binder phase content in the range of 1.2-2.5 times that of the nominal binder phase content of the bulk and it is essentially free from cubic carbides.

c) α -Al₂O₃ layer

[0014] The coating is composed of one or more refractory layers of which at least one layer is a texture-hardened α -Al₂O₃. The thickness of the α -Al₂O₃ layer is from 1 to 20, preferably 2-15, more preferably 4-12 and most preferably 4-7 μm . The α -Al₂O₃ layer is composed of columnar grains with a strong (0001) texture. The length/width ratio of the alumina grains is from 2 to 12, preferably 2 to 10, being dependent on the thickness of the layer. The α -Al₂O₃ layer is characterised by a (0006) diffraction peak at $2\theta = 41.675^\circ$ when Cu K α radiation is used. The other common diffraction peaks, such as (1012), (1014), (112 0), (112 3), (112 6) and (3 0 3 0) show low intensity. The texture coefficient (TC) for the alumina layer is determined according to the following formula:

$$\text{TC}(hkil) = \frac{I(hkil)}{I_0(hkil)} \left[\frac{1}{n} \sum_{n=1}^n \frac{I(hkil)}{I_0(hkil)} \right]^{-1} \quad (1)$$

where

$I(hkil)$ = intensity of the $(hkil)$ reflection

$I_0(hkil)$ = standard intensity according to JCPDS card no 46-1212

n = number of reflections used in the calculation

$(hkil)$ reflections used are: (1012) , (1014) , $(112\ 0)$, (0006) , $(112\ 3)$, $(112\ 6)$.

[0015] Consequently, $n = 6$ and the maximum value of the texture coefficient is 6.

[0016] When TC values for the TC(0006) reflection were measured for a large number of alumina layers and the obtained values were expressed as a function of the thickness of the layers the following curve could be fitted with the experimental data and, consequently, the preferred TC(0006) values can be expressed as follows:

$$TC(0006) \geq 1.33 \ln h + 2, h \in [1, 20]. \quad (2)$$

[0017] Equation 2 represents the lowest TC(0006) values obtained from the experimental layers varying in thickness, h , from about 1 to 20 μm . It is pointed out that better performance is obtained if the TC(0006) is higher than given by equation (2). For example, TC(0006) values larger than 4, preferably larger than 5, are preferred when the thickness, h , is $\geq 4\ \mu\text{m}$. The cutting tests clearly indicate that enhanced performance is obtained when $TC(0006) \geq 5$. These circumstances can be obtained when the CVD process is properly controlled with respect nucleation and growth. It is further noted, as clear from Equation 2, that the intensity of the (0006) peak and the TC(0006) are generally higher the thicker the CVD layer is, again on the condition that the CVD process is properly controlled. $TC(0006) > 3$, preferably > 4 , is acceptable for relatively thin alumina layers, less than 4 μm . The texture-hardened CVD alumina layer is under a tensile residual stress of about 0.5-1.0 GPa. It is emphasized that the $\alpha\text{-Al}_2\text{O}_3$ layer according to the present invention concerns as-deposited $\alpha\text{-Al}_2\text{O}_3$.

[0018] The $\alpha\text{-Al}_2\text{O}_3$ layer is further characterised by a shiny, preferably black, surface finish, which can be obtained by wet-blasting using an Al_2O_3 slurry. The surface roughness expressed as R_a should be $< 1.0\ \mu\text{m}$, preferably $< 0.7\ \mu\text{m}$, most preferably $< 0.5\ \mu\text{m}$.

d) Coating

[0019] The coating according to the present invention comprises a first layer adjacent the substrate of CVD Ti(C,N), CVD TiN, CVD TiC, MTCVD Ti(C,N), MTCVD Zr(C,N), MTCVD Ti(B,C,N), CVD HfN or combinations thereof preferably of Ti(C,N) having a thickness of from 1 to 20, preferably from 5 to 10, most preferably 5 to 8, μm . Said first layer is terminated by a bonding layer 0.5-1 μm thick of (Ti,Al)(C,O,N) preferably with increasing aluminium content towards the outer surface. Preferably, there is an intermediate layer of TiN between the substrate and said first layer with a thickness of $< 3\ \mu\text{m}$, preferably 0.5-2 μm .

[0020] In one embodiment the texture-hardened $\alpha\text{-Al}_2\text{O}_3$ layer described above is the uppermost layer. In another embodiment there is a layer of carbide, nitride, carbonitride or carboxynitride of one or more of Ti, Zr and Hf, having a thickness of from about 0.5 to 3 μm , preferably 0.5 to 1.5 μm atop the texture-hardened $\alpha\text{-Al}_2\text{O}_3$ layer described above. Also in this case the coating surface has a surface roughness measured as R_a as above.

e) Preferred embodiments

[0021] In one preferred embodiment the cutting tool insert has a composition of 6-9 wt-% Co and 6.5-9.5 wt-% cubic carbides of the metals from groups IVB, VB and VIB of the periodic table wherein the uppermost layer is a 4-7 μm thick, wet-blasted ($R_a < 1\ \mu\text{m}$), $\alpha\text{-Al}_2\text{O}_3$ layer composed of columnar grains with a length/width ratio from 2 to 15 and $TC(0006) \geq 4.5$. The coating further comprises a first layer adjacent the cemented carbide substrate being comprised of CVD Ti(C,N), CVD TiN, CVD TiC, MTCVD Ti(C,N), MTCVD Ti(C,O,N), MTCVD (Ti,Al)(C,O,N) or combinations thereof, preferably of Ti(C,N) having a thickness of from 4 to 10 μm , preferably from 5 to 7 μm .

[0022] In another preferred embodiment the cutting tool insert has a composition of 4-6 wt-% Co and 5-10 wt-% cubic carbides of the metals from groups IVB, VB and VIB of the periodic table wherein the uppermost layer is a 6-15 μm thick, wet-blasted ($R_a < 1\ \mu\text{m}$), $\alpha\text{-Al}_2\text{O}_3$ layer composed of columnar grains with a length/width ratio from 2 to 20 and $TC(0006) \geq 5.0$. The coating further comprises a first layer adjacent the cemented carbide substrate being comprised of CVD Ti(C,N), CVD TiN, CVD TiC, MTCVD Ti(C,N), MTCVD Ti(C,O,N), MTCVD (Ti,Al)(C,O,N) or combinations thereof, preferably of Ti(C,N) having a thickness of from 4 to 15 μm , preferably from 5 to 10 μm .

f) Method

[0023] The invention also relates to methods of making cutting tool inserts according to the description comprising a cemented carbide substrate consisting of a binder phase of Co, WC and a cubic carbonitride phase with a binder phase enriched surface zone essentially free of cubic phase and a coating. A powder mixture containing 4-9, preferably 5-8, most preferably 6-7 wt-% Co, and 6-10, preferably 6.5-9.5, most preferably 7.5-9 wt-% cubic carbides of the metals from groups IVB, VB and VIB of the periodic table, preferably Ti, Nb and Ta, and balance WC, preferably 84-88 wt-% WC. The ratio between the weight concentrations of Ta and Nb is within 1.0-3.0, preferably 1.5-2. The ratio between the weight concentrations of Ti and Nb is within 0.5-1.5, preferably 0.8-1.2. Well-controlled amounts of nitrogen are added through the powder e.g. as nitrides or by performing an in-situ nitriding in the furnace using e.g. nitrogen gas. The optimum amount of nitrogen to be added depends on the composition of the cemented carbide and in particular on the amount of cubic phases. The exact conditions depend to a certain extent on the design of the sintering equipment being used. It is within the purview of the skilled artisan to determine and to modify the nitrogen addition and the sintering process in accordance with the present specification in order to obtain the desired result.

[0024] The powder materials are mixed with pressing agent and tungsten or carbon in such a way that the desired S-value is obtained and the mixture is wet milled and spray dried to obtain a powder material with the desired properties. The powder is then compacted and sintered. Sintering is performed at a temperature of 1300-1500°C, in a controlled atmosphere of about 50 mbar followed by cooling.

[0025] After conventional post sintering treatments including edge rounding, a coating is applied using CVD and MTCVD techniques. The first layer is MTCVD Ti(C,N), optionally containing a thin, thickness <3 µm, preferably 0.5-2.0 µm TiN layer adjacent the substrate and additionally another optional TiN layer, thickness <3 µm, preferably 0.5-2.0 µm situated 0.5 to 2.5 µm below the alumina-Ti(C,N) interface.

[0026] The present invention also relates to a refined method to produce textured α -Al₂O₃ layers in a temperature range of 850-1050°C, preferably at 900-1000°C with a (0001) texture. The α -Al₂O₃ layer is deposited on a bonding layer of (Ti,Al)(C,O,N) preferably with increasing aluminium content towards the outer surface. On to this layer a Ti(C,O) layer is deposited with controlled O-content. A nucleation layer is obtained in the similar way as used in ALD (Atomic Layer Deposition). The procedure is as follows:

- (i) exposure of a first precursor TiCl₄, preferably together with AlCl₃,
- (ii) purge (N₂),
- (iii) exposure of the second precursor (H₂O) and
- (iv) purge (N₂). The duration of the steps (i) and (iii) is 1-5 min, preferably 2 min each and the steps (ii) and (iv) 2-10 min, preferably 5 min each.

The deposition of the α -Al₂O₃ is started with a relatively long 30-120 min, preferably 60 min, nucleation step without sulphur- or fluorine containing compounds. α -Al₂O₃ is grown to its desired thickness using sulphur-containing compounds H₂S, or SO₂, preferably H₂S, optionally together with fluorine-containing compounds SF₆ or HF, preferably SF₆. When α -Al₂O₃ is nucleated correctly, followed by a deposition process using relatively low amounts of these dopants together with a CO+CO₂ gas mixture, where CO=2.5-5.5 x CO₂, a stronger (0001) growth texture than known from the prior art can be obtained in a controlled way. Important difference compared with the prior-art is that the texture is controlled, in addition to the nucleation procedure, also during the growth of α -Al₂O₃ itself. The CO/CO₂ ratio is gradually increased from 2.5 to 5.5 during the CVD process to maintain the preferred growth direction. Consequently, the (0001) texture is stronger and the surface microstructure of the alumina layer differs from that known earlier being terminated by (1012) and (1014) surfaces. The described texture cannot be obtained unless both the nucleation and growth are controlled correctly. This is a possible explanation for the fact that the (0001) texture [(0006) diffraction peak] has been unknown so far.

[0027] After the coating operation the outermost layer is smoothed to obtain a shiny, preferably black, surface finish with a surface roughness expressed as R_a of <1.0 µm, preferably <0.7 µm, most preferably <0.5 µm which can be obtained by wet-blasting using an Al₂O₃ slurry. The R_a-value can easily be controlled by wet-blasting data e.g. pressure and time. There are naturally several other possible surface treatments, which can also be applied.

Example 1

[0028] Cemented carbide inserts of type CNMG120408-M5 and SNUN120408 with a composition of 6.6 wt% Co, 3,6 wt% TaC, 2.2 wt% NbC, 2,5 wt% TiC and balance WC, with a binder phase alloyed with W corresponding to an S-value of 0.83 were produced by conventional milling of the raw material powders, pressing of the green compacts and subsequent sintering at 1430°C. The nitrogen was added to the carbide powder as Ti(C,N). A microstructural investigation after sintering showed that a cubic carbide free zone with a thickness of about 20 µm was formed (Fig. 2a). The coercivity

was 11.8 kA/m corresponding to an average grain size of about 1 μm . This substrate is referred to as "substrate A".

Example 2 (comparative example)

[0029] From a similar powder mixture as used in Example 1, but without nitrogen additions, inserts of type CNMG120408-M5 and SNUN120408 were pressed and sintered according to a standard procedure. The inserts were examined and they did not exhibit any Co-enrichment. The average grain size was the same as in Example 1. This substrate is referred to as "substrate B".

Example 3

[0030] Cemented carbide cutting inserts from Examples 1 and 2 were coated with a layer of MTCVD Ti(C,N). The thickness of the MTCVD layer was about 6 μm . On to this layer four $\alpha\text{-Al}_2\text{O}_3$ layers consisting of about 6 μm $\alpha\text{-Al}_2\text{O}_3$ were deposited:

- a) (1012) textured $\alpha\text{-Al}_2\text{O}_3$ (according to prior art),
- b) (1014) textured $\alpha\text{-Al}_2\text{O}_3$ (according to prior art),
- c) (0001) textured $\alpha\text{-Al}_2\text{O}_3$ (invention) and
- d) (0001) textured $\alpha\text{-Al}_2\text{O}_3$ according to prior art US 2007/104945.

[0031] The layers will be referred to as layers a, b, c and d. For example, substrate A with layer a is referred to as Aa. Layer c was deposited according to the invention. Layer d was deposited using the prior-art process. The process used for layer c resulted in a stronger growth along the [0001] direction and the surfaces of the $\alpha\text{-Al}_2\text{O}_3$ grains of this layer were not terminated by the (0001) surfaces (invention).

[0032] The coated tools were wet-blasted using alumina particles to an Ra value of less than 0.8 μm . Fig. 3 shows a cross-section SEM micrograph of layer c before wet blasting. The alumina layer is composed of columnar grains with (0001) planes parallel to the substrate surface (arrowed). Fig. 4 shows SEM surface images of layers c and d demonstrating the above-discussed differences in the surface morphologies.

Example 4

[0033] Layers a), b), c) and d) were studied using X-ray diffraction. The-ray diffraction patterns are presented in Fig. 5. The absence of the (0006) diffraction peaks on layers a) and b) should be noticed. TC(1012), TC(1014) and TC(0006) were determined. The results are presented in Table 1. Note that two different (0001) textured alumina layers were produced (layers c and d with strong (0006) diffraction peaks). Layer c is according to the invention.

Table 1.

Layer	Peak indices (hkil)	TC(hkil)
a	(1012)	5.16
b	(1014)	4.23
c	(0006)	5.55 (invention)
d	(0006)	4.02 (prior-art)

Example 5

[0034] 60 cemented carbide cutting inserts from Example 1 were coated with a layer of MTCVD Ti(C,N). Ten inserts of these were coated with $\alpha\text{-Al}_2\text{O}_3$ alumina layers according to the present invention with following thicknesses: 2, 4, 6, 8, 10 and 15 μm (10 inserts/thickness). The alumina layers were deposited using identical processes. Diffraction peak intensities were determined by XRD and TC values were obtained by using Equation 1. The results are given in Table 2.

Table2

Layer thickness (μm)	TC (average of 10 inserts)
2	3.4 ± 0.4

(continued)

Layer thickness (μm)	TC (average of 10 inserts)
4	4.9 ± 0.6
6	5.2 ± 0.5
8	5.4 ± 0.4
10	5.5 ± 0.4
15	5.7 ± 0.2

Example 6

[0035] Layers a), b) and c) deposited on the binder phase enriched substrates from Example 1 were evaluated using a slotted bar test under the following conditions.

Work piece: Cylindrical slotted bar

Material: SS1672

Insert type: CNMG120408-M5

Cutting speed: 130 m/min

Feed: 0.1, 0.125, 0.16, 0.20, 0.25, 0.315, 0.4, 0.5, 0.63, 0.8 and 1.0 mm/rev gradually increased after 10 mm length of cut

Depth of cut: 2.0 mm

Remarks: dry turning

Tool life criteria: Gradually increased feed until edge breakage. Ten edges of each variant were tested.

[0036] The results are presented in Fig. 6 showing the number of the survived edges as a function of feed (mm/rev). Fig. 6 demonstrates that the layer texture is important for the properties of the tool. The (0001) texture-hardened layer outperforms the prior-art.

Example 7

[0037] The coated inserts from Examples 1-3 were tested with respect to toughness in a turning operation with interrupted cuts. The work piece material was SS2343.

Work piece: Cylindrical slotted bar

Material: SS2343

Insert type: CNMG120408-M5

Cutting speed: 70 m/min

Feed: 0.1, 0.125, 0.16, 0.20, 0.25, 0.315, 0.4, 0.5, 0.63, 0.8 and 1.0 mm/rev gradually increased after 10 mm length of cut

Depth of cut: 2.0 mm

Remarks: coolant, 15 edges of each variant were tested.

As clear from Table 3 the edge toughness was considerably enhanced when the layer was deposited according to the present invention on Binder phase enriched substrates. The test results showed that the layer according to the invention (layer c) exhibited clearly better toughness behaviour than the prior-art (layers a and b) when deposited on Binder phase enriched substrate.

Table 3

Substrate/Coating	Mean feed at breakage (mm)
Aa	0.31
Ab	0.40

(continued)

Substrate/Coating	Mean feed at breakage (mm)
Ac (invention)	0.64 (+60%as compared with Ab)
Ad (prior art)	0.49 (+23%as compared with Ab)
Ba	0.14
Bb	0.21
Bc	0.26 (+24% as compared with Bb)
Bd	0.24 (+14% as compared with Bb)

Example 8

[0038] The layers a), b), c) and d) were tested with respect to edge chipping in longitudinal turning in cast iron. This type of cast iron, even though it is not the preferred work piece material for this type of tool, was used to evaluate the edge-chipping tendency of the alumina layers.

Work piece: Cylindrical bar
 Material: SS0130
 Insert type: SNUN 120408
 Cutting speed: 220 m/min
 Feed: 0.4 mm/rev
 Depth of cut: 2.0 mm
 Remarks: dry turning

[0039] The inserts were inspected after 2 and 6 minutes of cutting. As clear from Table 4 the edge toughness of the prior art product was considerably enhanced when the layer was produced according to the present invention.

Table 4

	Flaking of the edge line (%) after 2 minutes	Flaking of the edge line (%) after 6 minutes
Aa	8	22
Ab	6	17
Ac (invention)	4	8
Ad (prior art)	4	12

Example 9

[0040] Layers a (prior-art), c (invention) and d (prior-art) from example 3 were tested in continuous turning in ordinary carbon steel using coolant. The following cutting data were used:

Work piece: Cylindrical bar
 Material: SS 1672
 Inert type: SNUN 120408
 Cutting speed 320 m/min
 Feed: 0.4 mm/rev
 Depth of cut: 2.0 mm
 Tool life criterion: Flank wear>0.3 mm.

[0041] The example demonstrates that the wear resistance is higher for the alumina layer with higher TC(0006) according to the invention. The test results are summarised in Table 5.

Table 5

Experimental Substrate/Coating	Tool life (min)
Coating Aa (prior-art)	5.2
Coating Ac(Invention)	11.5
Coating Ad (prior-art)	8.2

Claims

1. A cutting tool insert comprising a cemented carbide body and a coating, **characterized in that**

- the cemented carbide body comprises WC, 4-12, preferably 5-9 wt-% Co and 5-10, preferably 7.5-9.5, wt-% cubic carbides of the metals from groups IVb, Vb and VIb of the periodic table, preferably Ti, Nb and Ta, with an S-value of 0.79-0.90 and a coercivity of 9-18, preferably 10-15 kA/m at least one surface of the cemented carbide body comprises a binder phase enriched surface zone with a thickness of 5-50, preferably 5-30, μm being essentially free from cubic carbides adjacent a coating wherein at least one layer is a 1-20, preferably 2-15, μm thick nucleated $\alpha\text{-Al}_2\text{O}_3$ layer composed of columnar grains with a length/width ratio from 2 to 12 whereby the $\alpha\text{-Al}_2\text{O}_3$ layer has a texture coefficient TC(0006)

$$\text{TC}(0006) \geq 1.33 \ln h+2$$

where h is the thickness of the $\alpha\text{-Al}_2\text{O}_3$ -layer in μm and TC(0006) is defined as follows:

$$\text{TC}(hkl) = \frac{I(hkl)}{I_0(hkl)} \left[\frac{1}{n} \sum_{n=1}^n \frac{I(hkl)}{I_0(hkl)} \right]^{-1}$$

where

$I(hkl)$ = measured intensity of the (hkl) reflection

$I_0(hkl)$ = standard intensity according to JCPDS card no 46-1212

n = number of reflections used in the calculation.

(hkl) reflections used are: $(10\bar{1}2)$, $(10\bar{1}4)$, $(11\bar{2}0)$, (0006), $(11\bar{2}3)$, $(11\bar{2}6)$ whereby the coating comprises a first layer adjacent the body of CVD Ti(C,N), CVD TiN, CVD TiC, CVD HfN, MTCVD Ti(C,N), MTCVD Ti(C,O,N), MTCVD Zr(C,N), MTCVD Zr(C,O,N), MTCVD Ti(B,C,N), MTCVD (Ti,Al)(C,O,N) or combinations thereof preferably of Ti(C,N) having a thickness of from 1 to 20 μm , preferably from 5 to 10 μm and said texture-hardened $\alpha\text{-Al}_2\text{O}_3$ layer adjacent said first layer.

2. Cutting tool insert according claim 1 **characterised in** a binder phase enriched surface zone with a thickness of 5-30 μm being essentially free from cubic carbides adjacent a coating wherein at least one layer is a 4-15 μm thick $\alpha\text{-Al}_2\text{O}_3$ layer composed of columnar grains with a length/width ratio from 2 to 12 and $\text{TC}(0006) \geq 5$.
3. Cutting tool insert according claim 1 **characterised in** a binder phase enriched surface zone with a thickness of 5-30 μm being essentially free from cubic carbides adjacent a coating wherein at least one layer is a <4 μm thick $\alpha\text{-Al}_2\text{O}_3$ layer composed of columnar grains with a length/width ratio from 2 to 10 and $\text{TC}(0006) \geq 4$.
4. Cutting tool insert according to any of the previous claims **characterized in that** the $\alpha\text{-Al}_2\text{O}_3$ layer is the uppermost layer and with an R_a value <1.0 μm , preferably <0.7 μm .
5. Cutting tool insert according to any of claims 1-4 **characterized in that** a layer of carbide, nitride, carbonitride or carboxynitride of one or more of Ti, Zr and Hf, having a thickness of from 0.5 to 3 μm , preferably 0.5 to 1.5 μm is atop the $\alpha\text{-Al}_2\text{O}_3$ layer.
6. Cutting tool insert according to claim 5 **characterized in that** said layer is the uppermost layer and with an R_a -value <1.0 μm , preferably <0.5 μm .

7. Cutting tool insert according to claim 1 **characterised in** a composition of 6-9 wt-% Co and 6.5-9.5 wt-% cubic carbides of the metals from groups IVb, Vb and VIb of the periodic table wherein the uppermost layer is a 4-7 μm thick, wet-blasted ($R_a < 1 \mu\text{m}$), $\alpha\text{-Al}_2\text{O}_3$ layer composed of columnar grains with a length/width ratio from 2 to 15 and $\text{TC}(0006) \geq 4.5$, the coating further comprising a first layer adjacent the cemented carbide substrate being comprised of CVD Ti(C,N), CVD TiN, CVD TiC, MTCVD Ti(C,N), MTCVD Ti(C,O,N), MTCVD (Ti,Al)(C,O,N) or combinations thereof, preferably of Ti(C,N) having a thickness of from 4 to 10 μm , preferably from 5 to 7 μm .
8. Cutting tool insert according to claim 1 **characterised in** a composition of 4-6 wt-% Co and 5-10 wt-% cubic carbides of the metals from groups IVb, Vb and VIb of the periodic table wherein the uppermost layer is a 6-15 μm thick, wet-blasted ($R_a < 1 \mu\text{m}$), $\alpha\text{-Al}_2\text{O}_3$ layer composed of columnar grains with a length/width ratio from 2 to 20 and $\text{TC}(0006) \geq 5.0$, the coating further comprising a first layer adjacent the cemented carbide substrate being comprised of CVD Ti(C,N), CVD TiN, CVD TiC, MTCVD Ti(C,N), MTCVD Ti(C,O,N), MTCVD (Ti,Al)(C,O,N) or combinations thereof, preferably of Ti(C,N) having a thickness of from 4 to 15 μm , preferably from 5 to 10 μm .

Patentansprüche

1. Schneidwerkzeugeinsatz, umfassend einen Hartmetallkörper und eine Beschichtung, **dadurch gekennzeichnet, dass**

- der Hartmetallkörper WC, 4-12 Gewichts-%, vorzugsweise 5-9 Gewichts-%, Co und 5-10 Gewichts-%, vorzugsweise 7,5-9,5 Gewichts-%, kubische Carbide von den Metallen aus den Gruppen IVb, Vb und VIb des Periodensystems, vorzugsweise Ti, Nb und Ta, umfasst, mit einem S-Wert von 0,79-0,90 und einer Koerzitivkraft von 9-18 kA/m, vorzugsweise 10-15 kA/m, wobei wenigstens eine Oberfläche des Hartmetallkörpers einen mit Binderphase angereicherten Oberflächenbereich mit einer Dicke von 5-50 μm , vorzugsweise 5-30 μm , die in Nachbarschaft zu einer Beschichtung im wesentlichen frei von kubischen Carbiden ist, aufweist, wobei wenigstens eine Schicht eine 1-20 μm , vorzugsweise 2-15 μm , dicke kristallisierte $\alpha\text{-Al}_2\text{O}_3$ -Schicht ist, die aus säulenförmigen Körnern mit einem Länge-zu-Breite-Verhältnis von 2 bis 12 gebildet ist, wobei die $\alpha\text{-Al}_2\text{O}_3$ -Schicht einen Textur-Koeffizienten $\text{TC}(0006)$ aufweist,

$$\text{TC}(0006) \geq 1,33 \ln h+2,$$

wobei h die Dicke der $\alpha\text{-Al}_2\text{O}_3$ -Schicht in μm ist und $\text{TC}(0006)$ wie folgt definiert ist:

$$\text{TC}(hkl) = \frac{I(hkl)}{I_0(hkl)} \left[\frac{1}{n} \sum_{i=1}^n \frac{I(hkl)}{I_0(hkl)} \right]^{-1}$$

wobei

$I(hkl)$ = gemessene Intensität der (hkl)-Reflektion

$I_0(hkl)$ = Standardintensität gemäß JCPDS-Karte Nr. 46-1212

n = Anzahl der Reflektionen, die bei der Berechnung verwendet werden,

wobei die verwendeten (hkl)-Reflektionen: (1012), (1014), (1120), (0006), (1123), (11 $\bar{2}$ 6) sind, wobei die Beschichtung in Nachbarschaft zu dem Körper eine erste Schicht von CVD Ti(C,N), CVD TiN, CVD TiC, CVD HfN, MTCVD Ti(C,N), MTCVD Ti(C,O,N), MTCVD Zr(C,N), MTCVD Zr(C,O,N), MTCVD Ti(B,C,N), MTCVD (Ti,Al)(C,O,N) oder Kombinationen davon umfasst, vorzugsweise von Ti(C,N), mit einer Dicke von 1 bis 20 μm , vorzugsweise von 5 bis 10 μm , und die Texturgehärtete $\alpha\text{-Al}_2\text{O}_3$ -Schicht in Nachbarschaft zu der ersten Schicht.

2. Schneidwerkzeugeinsatz nach Anspruch 1, **gekennzeichnet durch** einen mit Binderphase angereicherten Oberflächenbereich mit einer Dicke von 5-30 μm , der in Nachbarschaft zu einer Beschichtung im wesentlichen frei von kubischen Carbiden ist, wobei wenigstens eine Schicht eine 4-15 μm dicke $\alpha\text{-Al}_2\text{O}_3$ -Schicht ist, die aus säulenförmigen Körnern mit einem Länge-zu-Breite-Verhältnis von 2 bis 12 und mit $\text{TC}(0006) \geq 5$ gebildet ist.

3. Schneidwerkzeugeinsatz nach Anspruch 1, **gekennzeichnet durch** einen mit Binderphase angereicherten Oberflächenbereich mit einer Dicke von 5-30 μm , der in Nachbarschaft zu einer Beschichtung im wesentlichen frei von kubischen Carbiden ist, wobei wenigstens eine Schicht eine $<4 \mu\text{m}$ dicke $\alpha\text{-Al}_2\text{O}_3$ -Schicht ist, die aus säulenförmigen Körnern mit einem Länge-zu-Breite-Verhältnis von 2 bis 10 und mit $\text{TC}(0006) \geq 4$ gebildet ist.
4. Schneidwerkzeugeinsatz nach einem der vorangehenden Ansprüche, **dadurch gekennzeichnet, dass** die $\alpha\text{-Al}_2\text{O}_3$ -Schicht die oberste Schicht ist, und mit einem Ra-Wert $<1.0 \mu\text{m}$, vorzugsweise $<0.7 \mu\text{m}$.
5. Schneidwerkzeugeinsatz nach einem der Ansprüche 1-4, **dadurch gekennzeichnet, dass** eine Schicht von Carbid, Nitrid, Carbonitrid oder Carboxynitrid von einem oder mehreren von Ti, Zr und Hf mit einer Dicke von 0,5 bis 3 μm , vorzugsweise 0,5 bis 1,5 μm , auf der $\alpha\text{-Al}_2\text{O}_3$ -Schicht ist.
6. Schneidwerkzeugeinsatz nach Anspruch 5, **dadurch gekennzeichnet, dass** die Schicht die oberste Schicht ist, und mit einem Ra-Wert $<1,0 \mu\text{m}$, vorzugsweise $<0,5 \mu\text{m}$.
7. Schneidwerkzeugeinsatz nach Anspruch 1, **gekennzeichnet durch** eine Zusammensetzung von 6-9 Gewichts-% Co und 6,5-9,5 Gewichts-% kubischen Carbiden von den Metallen aus den Gruppen IVb, Vb und VIb des Periodensystems, wobei die oberste Schicht eine 4-7 μm dicke, naßgestrahlte ($\text{Ra} < 1 \mu\text{m}$) $\alpha\text{-Al}_2\text{O}_3$ -Schicht ist, die aus säulenförmigen Körnern mit einem Länge-zu-Breite-Verhältnis von 2 bis 15 und mit $\text{TC}(0006) \geq 4,5$ gebildet ist, wobei die Beschichtung weiterhin in Nachbarschaft zu dem Hartmetallsubstrat eine erste Schicht aufweist, die von CVD $\text{Ti}(\text{C},\text{N})$, CVD TiN , CVD TiC , MTCVD $\text{Ti}(\text{C},\text{N})$, MTCVD $\text{Ti}(\text{C},\text{O},\text{N})$, MTCVD $(\text{Ti},\text{Al})(\text{C},\text{O},\text{N})$ oder Kombinationen davon gebildet ist, vorzugsweise von $\text{Ti}(\text{C},\text{N})$, mit einer Dicke von 4 bis 10 μm , vorzugsweise von 5 bis 7 μm .
8. Schneidwerkzeugeinsatz nach Anspruch 1, **gekennzeichnet durch** eine Zusammensetzung von 4-6 Gewichts-% Co und 5-10 Gewichts-% kubischen Carbiden von den Metallen aus den Gruppen IVb, Vb und VIb des Periodensystems, wobei die oberste Schicht eine 6-15 μm dicke, naßgestrahlte ($\text{Ra} < 1 \mu\text{m}$), $\alpha\text{-Al}_2\text{O}_3$ -Schicht ist, die aus säulenförmigen Körnern mit einem Länge-zu-Breite-Verhältnis von 2 bis 20 und mit $\text{TC}(0006) \geq 5,0$ gebildet ist, wobei die Beschichtung weiterhin in Nachbarschaft zu dem Hartmetallsubstrat eine erste Schicht aufweist, die von CVD $\text{Ti}(\text{C},\text{N})$, CVD TiN , CVD TiC , MTCVD $\text{Ti}(\text{C},\text{N})$, MTCVD $\text{Ti}(\text{C},\text{O},\text{N})$, MTCVD $(\text{Ti},\text{Al})(\text{C},\text{O},\text{N})$ oder Kombinationen davon gebildet ist, vorzugsweise von $\text{Ti}(\text{C},\text{N})$, mit einer Dicke von 4 bis 15 μm , vorzugsweise von 5 bis 10 μm .

Revendications

1. Un insert d'outil de coupe comprenant un corps en carbure cémenté et un revêtement, **caractérisé en ce que**

- le corps en carbure cémenté comprend du WC, entre 4 et 12 %, de préférence entre 5 et 9 % en poids de Co et entre 5 et 10, de préférence entre 7,5 et 9,5, % en poids de carbures cubiques de métaux des groupes IVb, Vb et VIb du tableau périodique, de préférence de Ti, Nb et Ta, avec un coefficient S de 0,79 à 0,90 et une coercivité de 9 à 18, de préférence de 10 à 15, kA/m, au moins une surface du corps en carbure cémenté comprenant une zone de surface enrichie avec une phase de liant, avec une épaisseur de 5 à 50, de préférence de 5 à 30, μm étant sensiblement dépourvue de carbures cémentés, au voisinage d'un revêtement dans lequel au moins une couche est une couche d' $\alpha\text{-Al}_2\text{O}_3$ nucléé de 1 à 20, de préférence de 2 à 15, μm d'épaisseur composée de grains en colonnes avec un rapport longueur/épaisseur de 2 à 12, la couche d' $\alpha\text{-Al}_2\text{O}_3$ ayant un coefficient de texture $\text{TC}(0006)$

$$\text{TC}(0006) \geq 1.33 \ln h + 2$$

Où h est l'épaisseur de la couche d' $\alpha\text{-Al}_2\text{O}_3$ en μm et $\text{TC}(0006)$ est défini comme suit :

$$\text{TC}(\text{hkil}) = \frac{\text{I}(\text{hkil})}{\text{I}_0(\text{hkil})} \left[\frac{1}{n} \sum_{n=1}^n \frac{\text{I}(\text{hkil})}{\text{I}_0(\text{hkil})} \right]^{-1}$$

où :

$I(hkil) = 1$ (intensité mesurée de la réflexion $(hkil)$)

$I_0(hkil)$ = l'intensité standard selon la carte JCPDS n° 46-1212

n = nombre de réflexions utilisées pour le calcul.

Les réflexions $(hkil)$ utilisées sont : $(10\bar{1}2)$, $(10\bar{1}4)$, $(11\bar{2}0)$, (0006) , $(11\bar{2}3)$, $(11\bar{2}6)$, dans lequel le revêtement comprend une première couche au voisinage du corps en CVD Ti(C, N), CVD TiN, CVD TiC, CVD HfN, MTCVD Ti(C, N), MTCVD Ti(C,O,N), MTCVD Zr(C,N), MTCVD Zr(C,O,N), MTCVD Ti(B,C,N), MTCVD (Ti,Al)(C,O,N) ou de combinaisons de ceux-ci, de préférence en Ti(C,N), ayant une épaisseur de 1 à 20 μm , de préférence de 5 à 10 μm et ladite couche d' $\alpha\text{-Al}_2\text{O}_3$ de texture durcie au voisinage de ladite première couche.

2. Insert d'outil de coupe selon la revendication 1, **caractérisé par** une zone de surface enrichie avec une phase de liant avec une épaisseur de 5 à 30 μm étant sensiblement dépourvue de carbures cubiques au voisinage d'un revêtement dans lequel au moins une couche est une couche d' $\alpha\text{-Al}_2\text{O}_3$ de 4 à 15 μm d'épaisseur composée de grains en colonnes avec un rapport longueur/épaisseur de 2 à 12 et un $\text{TC}(0006) \geq 5$.

3. Insert d'outil de coupe selon la revendication 1, **caractérisé par** une zone de surface enrichie avec une phase de liant avec une épaisseur de 5 à 30 μm étant sensiblement dépourvue de carbures cubiques au voisinage d'un revêtement dans lequel au moins une couche est une couche d' $\alpha\text{-Al}_2\text{O}_3$ d'épaisseur inférieure à 4 μm d'épaisseur composée de grains en colonnes avec un rapport longueur/épaisseur de 2 à 10 et un $\text{TC}(0006) \geq 4$.

4. Insert d'outil de coupe selon l'une quelconque des revendications précédentes, **caractérisé en ce que** la couche d' $\alpha\text{-Al}_2\text{O}_3$ est la couche supérieure et avec une valeur de $R_a < 1,0 \mu\text{m}$, de préférence $< 0,7 \mu\text{m}$.

5. Insert d'outil de coupe selon l'une quelconque des revendications 1 à 4, **caractérisé en ce qu'une** couche de carbure, de nitrure, de carbonitrure ou de carboxynitrure d'un ou plusieurs parmi Ti, Zr et Hf, ayant une épaisseur comprise entre 0,5 et 3 μm , de préférence entre 0,5 et 1,5 μm est au sommet de la couche d' $\alpha\text{-Al}_2\text{O}_3$.

6. Insert d'outil de coupe selon la revendication 5, **caractérisé en ce que** ladite couche est la couche supérieure et avec une valeur de $R_a < 1,0 \mu\text{m}$, de préférence $< 0,5 \mu\text{m}$.

7. Insert d'outil de coupe selon la revendication 1, **caractérisé par** une composition de 6 à 9 % en masse de Co et de 6,5 à 9,5 % en masse de carbures cubiques de métaux parmi les groupes IVb, Vb et VIb du tableau périodique, dans lequel la couche supérieure est une couche de 4 à 7 μm d'épaisseur, projetée à l'état humide ($R_a < 1 \mu\text{m}$), composée de grains en colonnes avec un rapport longueur/épaisseur comprise entre 2 et 15 et un $\text{TC}(0006) \geq 4,5$, le revêtement comprenant en outre une première couche au voisinage du substrat de carbures cimentés constituée de CVD Ti(C,N), CVD TiN, CVD TiC, MTCVD Ti(C,N), MTCVD Ti(C,O,N), MTCVD (Ti,Al)(C,O,N) ou de combinaisons de ceux-ci, de préférence de Ti(C,N) ayant une épaisseur comprise entre 4 et 10 μm , de préférence de 5 à 7 μm .

8. Insert d'outil de coupe selon la revendication 1, **caractérisé par** une composition de 4 à 6 % en masse de Co et de 5 à 10 % en masse de carbures cubiques des métaux des groupes IVb, Vb et VIb du tableau périodique dans lequel la couche supérieure est une couche d' $\alpha\text{-Al}_2\text{O}_3$ de 6 à 15 μm d'épaisseur, projetée à l'état humide ($R_a < 1 \mu\text{m}$), composée de grains en colonne avec un rapport longueur/épaisseur compris entre 2 et 20 et un $\text{TC}(0006) \geq 5,0$, le revêtement comprenant en outre une première couche au voisinage du substrat de carbures cimentés constitué de CVD Ti(C,N), CVD TiN, CVD TiC, MTCVD Ti(C,N), MTCVD Ti(C,O,N), MTCVD (Ti,Al)(C,O,N) ou de combinaisons de ceux-ci, de préférence de Ti(C,N), ayant une épaisseur de 4 à 15 μm , de préférence de 5 à 10 μm .

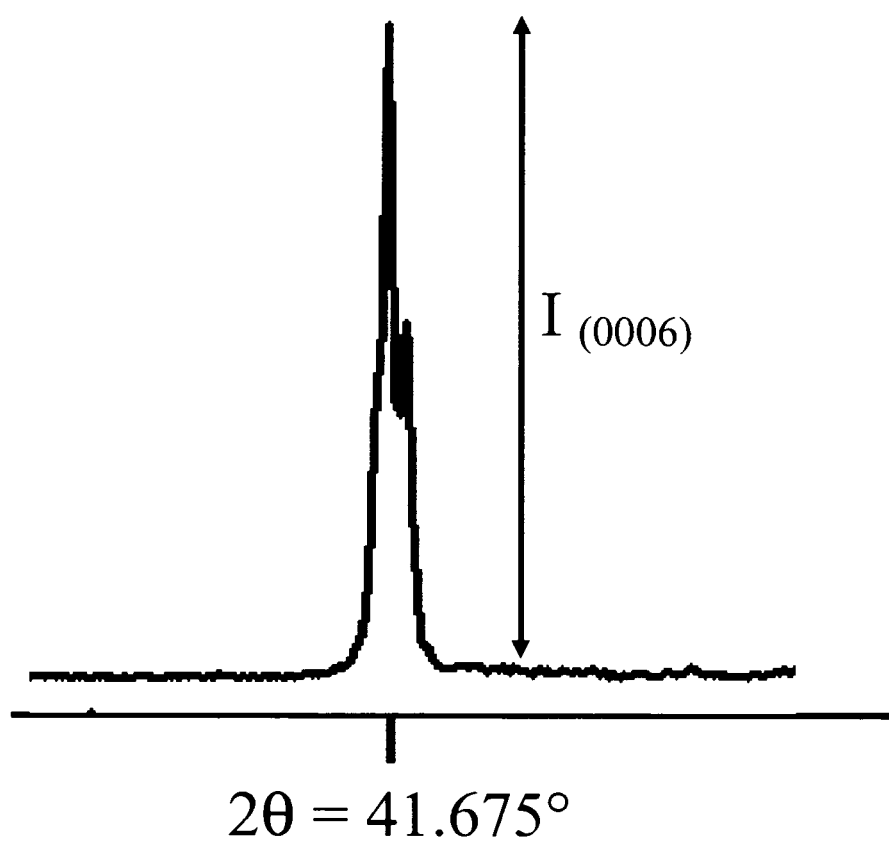


Fig. 1

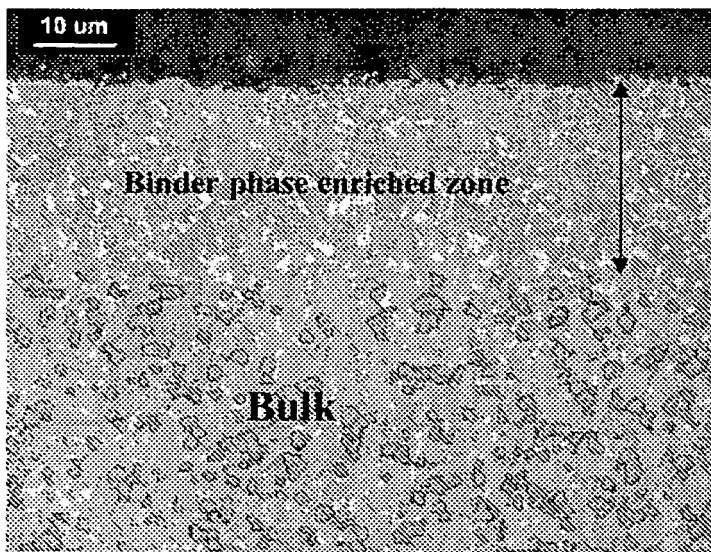


Fig. 2a

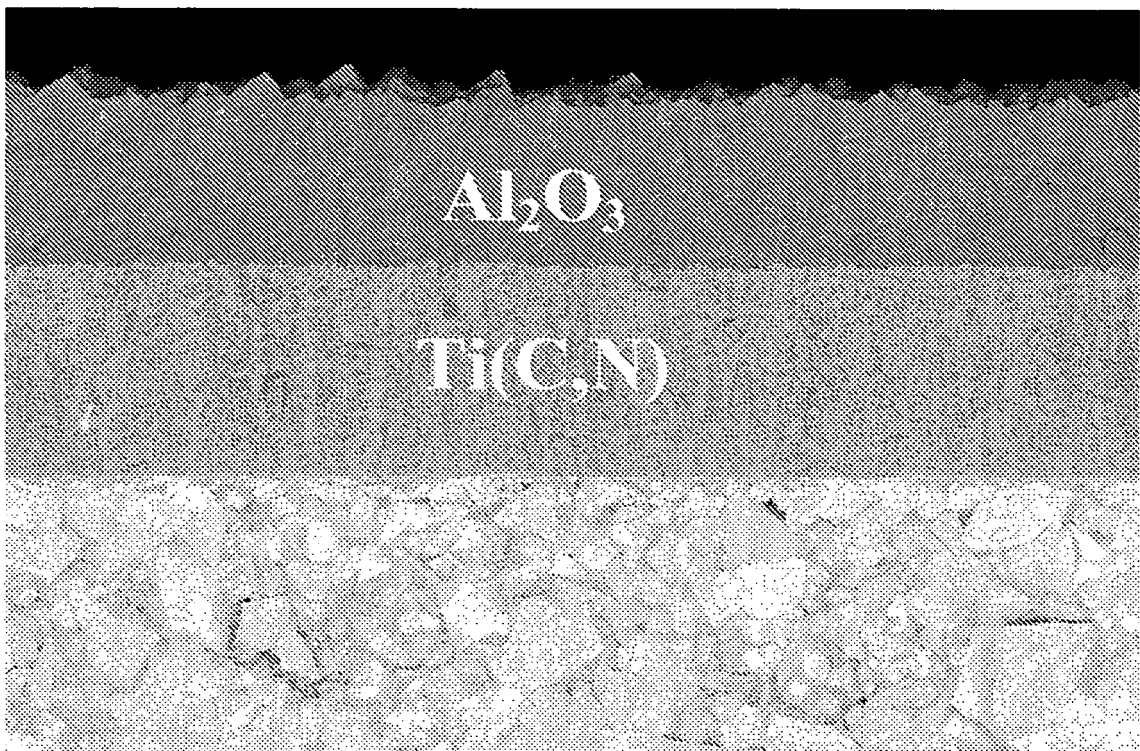


Fig. 2b

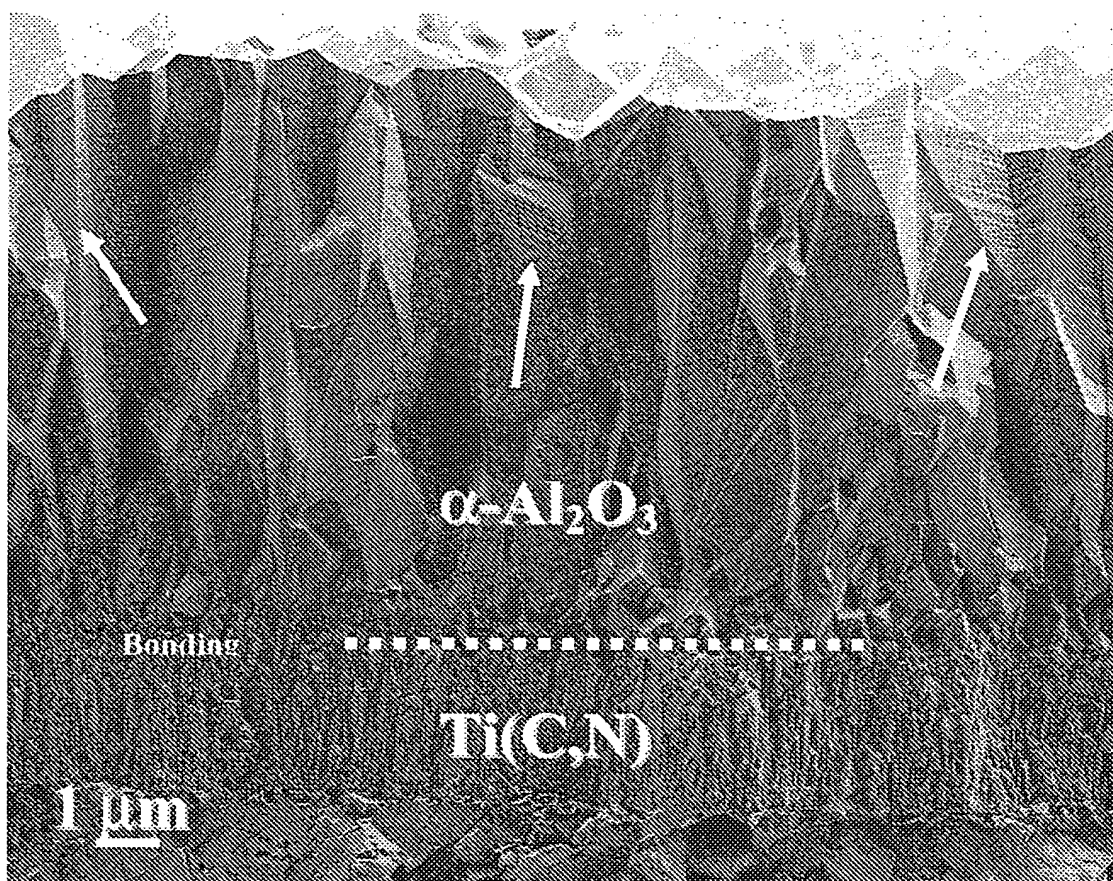


Fig. 3

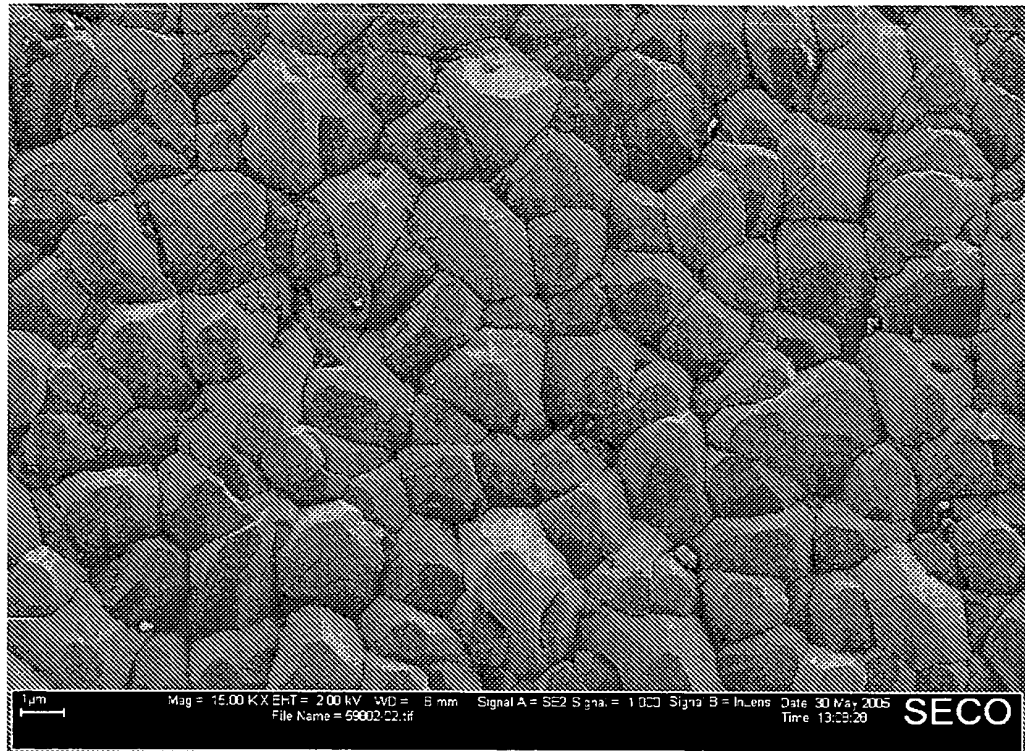


Fig. 4a

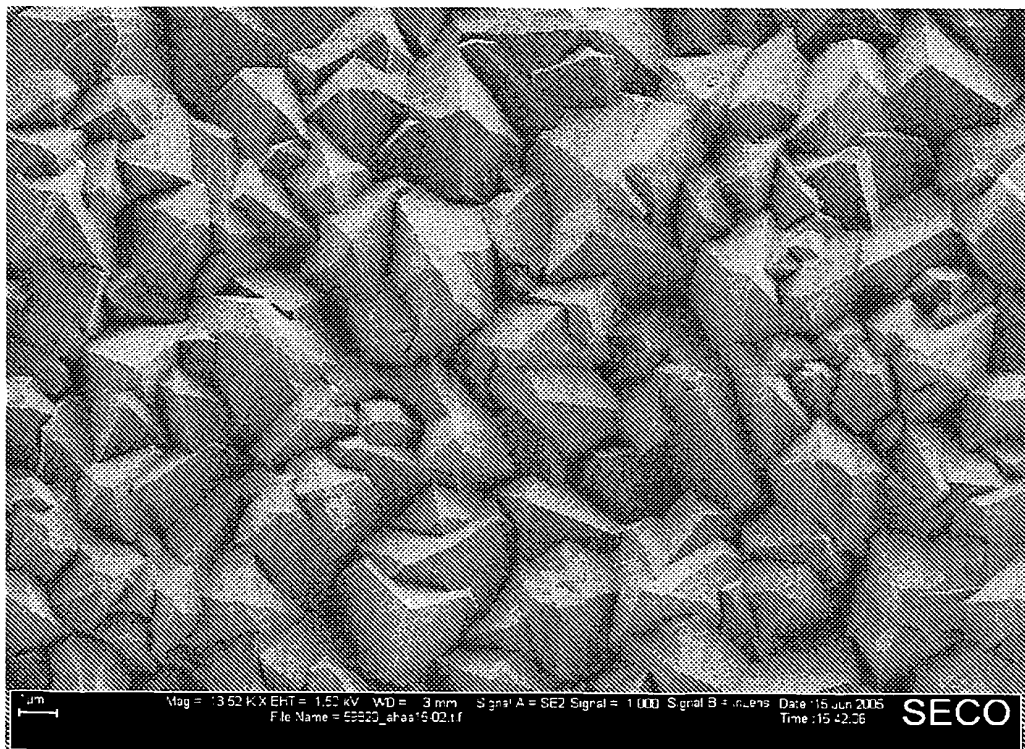


Fig. 4b

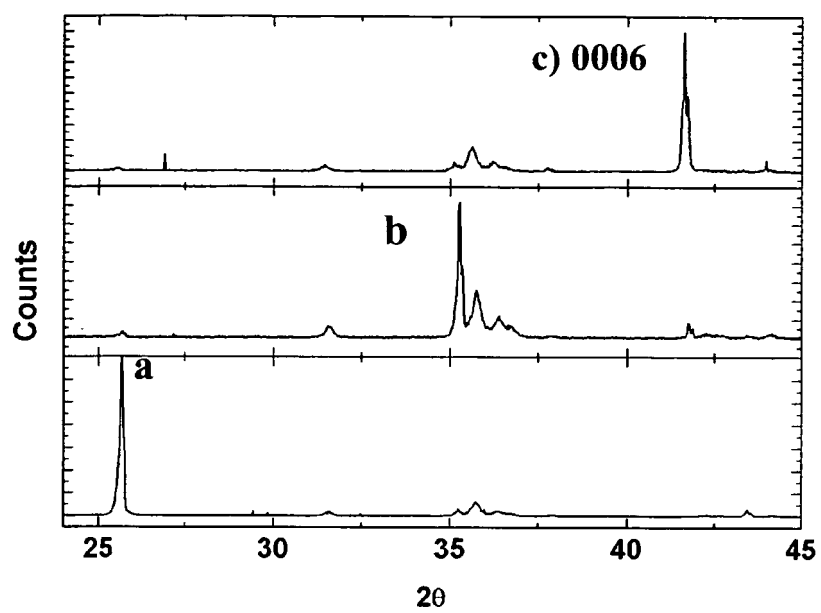


Fig. 5

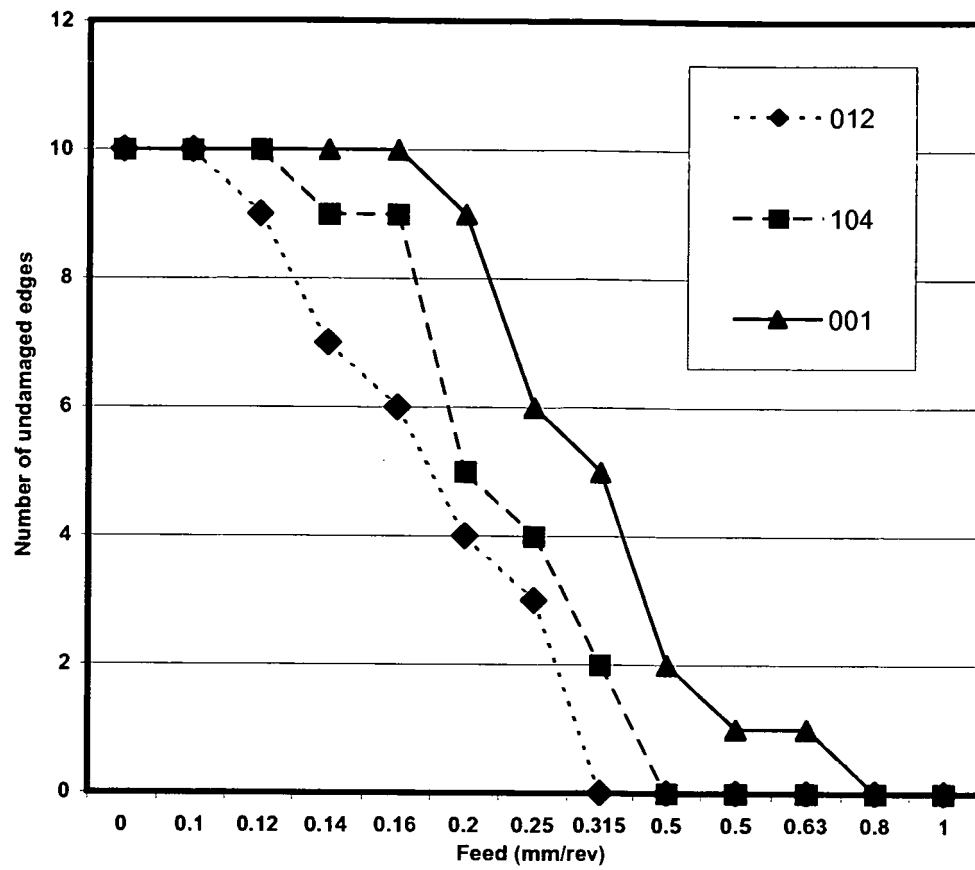


Fig. 6

REFERENCES CITED IN THE DESCRIPTION

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